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THE PACIFIC NORTHWEST RAINFALL SIMULATOR: A RESEARCH TOOL FOR THE INTERIOR NORTHWEST

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INTRODUCTION

Rainfall simulation provides researchers a method to evaluate the hydrologic and erodibility properties of agronomic practices. It provides experimental control and repeatability. We can not depend on natural rainfall to occur when and where it is needed to experimentally evaluate soil hydrologic and erodibility properties. Simulated rainfall, however, controls storm location, storm intensity and duration, aids in timeliness of data collection, allows for all-season data collection, and increases the ease by which several treatments can be evaluated at one time. Our ability to simultaneously collect hydrologic and erodibility data from multiple treatments reduces variability caused by changing weather and soil conditions, and thus provides us with an even-handed evaluation.

New farm management techniques designed to contribute to soil and water conservation are generally evaluated for their effectiveness under extreme conditions, typically a 100-year storm, or as is the case in the Pacific Northwest (PNW), a 100-year rainstorm onto frozen soil. It is unlikely that a 100-year storm will occur when we need it for research. With rainfall simulation, we can simulate multiple 100-year storms and recreate storm attributes within a particular season so that climate, soil, and plant growth conditions are relatively constant. By conducting rainfall simulations when there is much potential for erosion and runoff, we evaluate management methods under the worst case scenario. We assume that the treatments will respond in the same relative fashion for less severe conditions.

The use and development of rainfall simulators began in the 1930's in the mid-western and south-central United States where erosive storms are typically convectional, monsoonal, or both. These simulators produce higher intensity rainstorms with larger raindrop sizes than storms in the PNW. Typically, storms in the PNW have intensities less than 1/3 inch per hour (in/hr) and have a median drop size approximately two-thirds the size of the high intensity simulators.

Erosion in the dryland farming area of the PNW occurs predominately during the winter months as a result of low intensity rainstorms, snow melt on frozen soil, or both (Zuzel et al., 1987). The highest intensity rainfall during 31 years of record in Pendleton was 0.52 in/hr in May 1949, outside of the frozen soil erosion season. In the months when soil freezing occurs, October through March, the highest intensity recorded was 0.43 in/hr. Ninety percent of the rain on the Columbia Plateau falls at an intensity less than 0.10 in/hr (Brown et al. 1983). Because the vast majority of rain storms occurring in the inland PNW are low intensity, the process of soil erosion is not driven to the same degree by impact energy as it would be if storms were of the convectional type. In the PNW, we are concerned with the erosion processes of saturation and movement at the soil surface over soil that remains frozen.

Bubenzer et al. (1985) designed a low intensity rainfall simulator (the Palouse Rainfall Simulator) to produce rainfall typical of rain storms occurring naturally in the PNW. Rainfall could be applied simultaneously to two 6 ft. x 6 ft. plots. Plots with longer lengths, more suitable for rill development research, were considered possible if multiple units were assembled, unfortunately the support platform made such a combination impractical. Our objective in designing the Pacific Northwest Rainfall Simulator (PNW Rainfall Simulator) was to enhance the Palouse simulator by maintaining the distribution and physical characteristics of the raindrops while increasing the size and number of plots that could be simultaneously evaluated, increasing control of the nozzle performance, and automating data collection.

SIMULATOR DEVELOPMENT

The central unit of the Palouse simulator is the rotating disk and nozzle assembly. We began with this foundation and made changes to everything except the nozzle. Bubenzer et al. (1985) chose a 1/4HH14WSQ Full Jet nozzle for its ability to produce a drop size distribution similar to naturally occurring rainstorms and uniform areal coverage at low flow volumes. We discussed these criteria with industry representatives, re-examined the specifications, and decided to continue using the same nozzle. The nozzle produces drops with a median diameter of 0.07 inches and a rainfall intensity of 1.4 in/hr when operated at 15 psi. The rotating disk has four equal size spoke/openings that decrease the intensity of the rainfall by one half to 0.70 in/hr. Further adjustment of the intensity is controlled by the number of openings that are not covered by slats during simulations

Bubenzer et al. (1985) had modified a design by Amerman et al. (1970) and Rawitz et al. (1972). We further modified the design with these changes:

1. Reducing the size and weight of the nozzle platform.
2. Developing a structure that both supported the nozzle platform and served as a wind guard frame;
3. Redesigning the nozzle platform to be easily suspended from the wind guard frame.
4. Redesigning the nozzle platform and rotor to reduce the creation of drip points and splash surfaces that create large drops continuously at single points over plots.
5. Developing a system of shutters to provide rainfall intensities of 0.70, 0.53, 0.35, and 0.18 in/hr.
6. Instrumenting nozzles for monitoring water pressure. Each nozzle was plumbed for independent pressure adjustment.
7. Providing temperature sensors to measure water temperature falling on the plot, runoff, and air temperature within the rainfall simulator.
8. Instrumenting collection tanks to provide a continuous record of runoff.
9. Spacing nozzles to produce even coverage across larger plots than the simulator has been used for in the past.

SIMULATOR TESTING

McCool et al. (1978) and the nozzle manufacturer tested the nozzle for droplet size and droplet size distribution. Our major objective with attempting to enhance the simulator was to manufacture a simulator that would produce an even areal distribution across larger plots than the Palouse Simulator.

Initial calibration consisted of creating depth/volume tables for the runoff collection tanks at two water temperatures, and preliminary tests of the areal distribution of rainfall. We tested distribution within the 5 ft x 30 ft area using 3.125 inch diameter cans, spaced 14 inches apart. In these tests, nozzles were operated for 30 minutes, the water in the cans measured, and the intensity in inches per hour calculated. The coefficient of application uniformity (Christiansen, 1942) was and will be used to evaluate nozzle performance and relative positioning within each module at the previously mentioned intensities. The coefficient of application uniformity is:

Cu = [1 - (Average deviation from mean\mean depth applied)]*100

RESULTS AND DISCUSSION

The construction of the PNW Rainfall Simulator required an intensive team effort that began in August. We began, examined, and abandoned several avenues of design that looked promising initially, but initial testing proved them to be unacceptable. For instance one of our goals was to keep the weight of the unit as low as possible to improve portability and storage, and reduce set-up time in the field. The nozzle platform, which includes the rotating disk assembly, is one of the bulkiest and heaviest components. An alternative intensity control to the rotating disk design is the sweep design used in the Lafayette and Purdue Rainfall Simulators (Meyer and McCune, 1958; Foster et al. 1979). The nozzle used in the sweep design produces a narrow-fan pattern, which cuts off quickly when swept over a rectangular opening. The 1/4HH14WSQ Full Jet nozzle used produces a wide-square pattern, which we were not able to adapt to the sweep design. We thought we might eliminate the weight and the space requirements of the disk assembly by using an electrical solenoid shut-off to control the intensity. Unfortunately, nozzle performance was unacceptable with this method because of pressure fluctuations at the nozzle. Lacking a viable alternative, we redesigned the rotating disk assembly. It is now smaller, constructed of aluminum, easily installed on the support frame, and has fewer drip points than the original rotating disk assembly.

A major problem faced with the development and use of any rainfall simulator is the wind. Wind commonly occurs with natural rainfall, but simulated rainfall falls outside of the plot if the slightest of breezes is present. This problem is especially troublesome to efforts to simulate the rainfall characterized by small drops common in the PNW during rapid warming events associated with high winds. One solution to this problem is to block the wind using a sheet of plastic supported by fence posts. This solution is often used for small plots (3 ft x 3 ft). On larger plots, the simulations are conducted during periods without wind, usually in the morning hours shortly after daybreak. These methods work well if the plot size is small and the equipment extremely portable, however, given the amount of time required to set up a simulator for large plots, the schedule can not be dependent upon the vagaries of the weather. An efficient wind guard would also support the nozzle platforms. A Quonset-style portable garage serves as both wind guard and support.

One test at two levels of rainfall intensity has been completed for one rainfall simulator module. The Christiansen coefficient values are 85 for 0.73 in/h and 80 at 0.33 in/h. These values compare well with values obtained by Bubenzer et al. (1985) for areal distribution of a single nozzle at various rates (Table 1).

SUMMARY

The PNW Rainfall Simulator is a modified design of the Palouse Simulator. The new rainfall simulator is portable, rug ged, produces four rainfall intensities, and is instrumented to monitor nozzle pressures for control of rainfall drop size and distribution characteristics. With a four-module set, we can simultaneously apply rainfall onto four 5 ft x 30 ft plots to study the influence of soil and crop residue management systems on rill formation and erosion under PNW rainfall conditions, and collect data on air, soil, and water temperature and runoff. Each module

Table 1. Uniformity of rainfall application results, January, 1996, Pendleton OR.

Intensity	Uniformity of application (%) Size of Plot	
in/h	6.5 ft x 6.5 ft	5 ft x 30 ft
0.24	80	-
0.35	-	80
0.47	90	-
0.70	-	85
0.91	90	-

consists of three nozzle platforms housed inside of a Quonset-style shelter, which proved easy to move and also protected rainfall distribution from wind. We successfully used the PNW Rainfall Simulator in February 1996 to evaluate soil erosion control of four tillage systems under soil thaw conditions critical to PNW erosion events.

The PNW Rainfall Simulator will be used in coming years, during all seasons, to evaluate soil and water conservation in crop residue management and tillage systems. In the future, it will be used to develop basic seasonal knowledge of soil hydrologic and erodibility properties, evaluate new tillage methods and residue management systems, and elucidate the role of hillslope processes for use in watershed models such as the Watershed Erosion Prediction Project (WEPP).

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